Face-gender discrimination is possible in the near-absence of attention

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The attentional cost associated with the visual discrimination of the gender of a face was investigated. Participants performed a face-gender discrimination task either alone (single-task) or concurrently (dual-task) with a known attentional demanding task (5-letter T/L discrimination). Overall performance on face-gender discrimination suffered remarkably little under the dual-task condition compared to the single-task condition. Similar results were obtained in experiments that controlled for potential training effects or the use of low-level cues in this discrimination task. Our results provide further evidence against the notion that only low-level representations can be accessed outside the focus of attention.

Keywords: attention, face-gender discrimination, dual-task

Introduction

Simple visual tasks such as orientation or color discrimination can be performed in the near-absence of spatial attention (Treisman & Gelade, 1980; Julesz, 1981; Braun & Sagi, 1990; Braun, 1993; Braun, 1994; Braun & Julesz, 1998). In contrast, participants are unable to perform slightly more "complex" tasks, such as discriminating between the arbitrarily rotated letters T and L or between two spatial arrangements of colors, when spatial attention is engaged elsewhere (Lee Koch, & Braun, 1999; Li, VanRullen, Koch, Perona, 2002). However, recently Li et al. (2002) showed on the basis of a dual-task paradigm (Sperling & Melchner, 1978; Sperling, 1986; Braun & Sagi, 1990; Braun & Julesz, 1998) that natural scenes (e.g., animal vs. non-animal) can be categorized in the near-absence of spatial attention. Using event related potentials (ERP), Rousselet, Fabre-Thorpe, and Thorpe (2002) have come to a similar conclusion with regard to object detection in natural scenes (animal vs. non-animal). These results are surprising because, from a computational point of view, natural scene categorization is substantially more "complex" than a letter discrimination task. It is thus not necessarily the "complexity" of the visual discrimination task that determines whether it can be performed in the near-absence of attention; the type of stimuli used (natural scenes and objects vs. simpler, synthetic stimuli, such as T vs. L) also plays an important role in determining the attentional demands of the task.

By extension, one could speculate whether this form of spatial attention (the specific resource that is engaged by the T/L discrimination) actually plays the same role in the natural visual environment as it does in artificial laboratory settings, where the visual world is composed of bars, letters, and other synthetic patterns briefly flashed on an otherwise blank screen. In other words, where does this ability to process natural stimuli in the absence of spatial attention break down? To answer this question, we chose a task that involved a fine discrimination of the spatial arrangement of features that are present in both targets and distracters. We investigated the attentional demands of face-gender processing.

Numerous experiments have explored the attentional demands of face processing. Although faces are believed to be of particular importance to the visual system (Farah, 1995; Kanwisher, McDermott, & Chun, 1997; Farah, Wilson, Drain, & Tanaka, 1998; Ro, Russell, & Lavie, 2001), most studies have failed to demonstrate a pop-out effect for faces in visual search (Nothdurft, 1993; Kuehn & Jolicoeur, 1994; Purcell, Stewart, & Skov, 1996; Brown, Huey, & Findlay, 1997). This suggests that face processing requires some form of attention. However, this result is still controversial (Hansen & Hansen, 1988; Suzuki & Cavanagh, 1995; Hochstein & Ahissar, 2002), and it is hoped that the present experiments will contribute to resolving this debate.

Methods

Participants

Six participants, including one of the authors (LR), were tested in Experiments 1,2, and 3. Six additional participants were tested on Experiment 4 while another six were tested on Experiment 5. All participants (aged from

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22 to 31 years) were undergraduate and graduate students or staff at the California Institute of Technology and were paid $13.50 per hour. By self-report they had normal or corrected-to-normal acuity.

Face database

The face stimuli used were obtained from the Max Planck Institute, Tübingen, Germany, and contained seven views of 100 male and 100 female faces (Troje & Bulthoff, 1996). This database of colored photographs is well matched for low-level features such as color, size, and illumination. Pilot experiments showed that the gender of some faces in the database was ambiguous with overall discrimination performance around 65%. Therefore, eight additional participants were asked to judge the gender of each face and rate their confidence on a 3-point Likert scale. The mean of these responses was converted into *Z*-scores. Each face was randomly presented 10 times for 1000 ms. The present gender-discrimination experiment used the 50 male and 50 female individuals that produced the highest mean male and female ratings. Examples of the faces used are shown in Figure 1b.

Apparatus

Participants were seated approximately 120 cm from a computer monitor connected to a Silicon Graphics (O2) computer for the dual-task experiments. The refresh rate of the monitor was 75 Hz. The face rating (described above) and face recognition experiments (Experiment 3) were performed on a Macintosh G4 computer; the refresh rate of

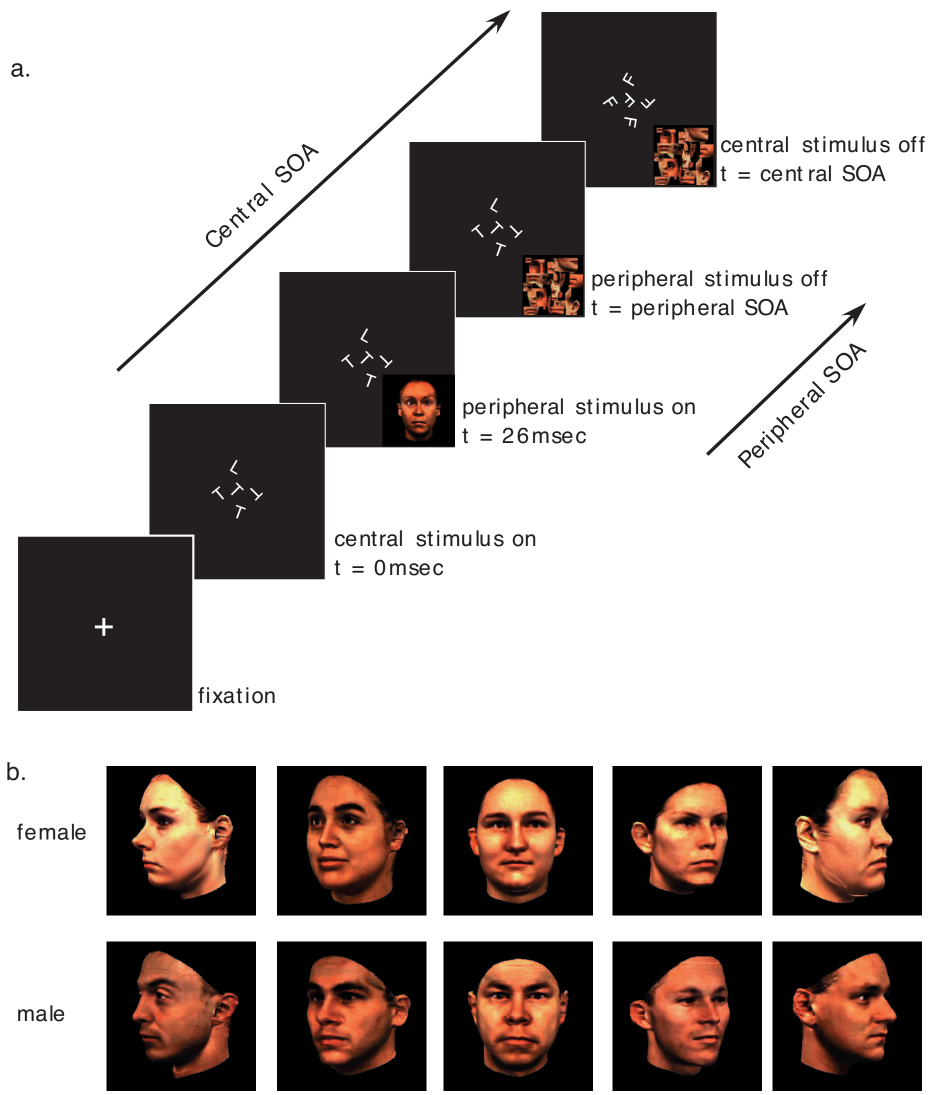


Figure 1. Face-gender discrimination dual-task experiment. a. Schematic timeline for one trial in the dual-task experiment. At the end of a trial, participants are required to report the gender of the face presented and/or whether the 5 central letters were the same (either 5Ts or 5Ls) or different (4Ts and 1L or 4Ls and 1T). All trials are arranged similarly, independent of the specific instructions. Both letters and faces were masked individually. Central SOA (~200 ms) and peripheral SOA (~145 ms) indicate the presentation time for letters and faces, respectively. b. Exemplars of male and female faces used in the experiment.

the monitor was 75 Hz. The display was synchronized with the vertical retrace of the monitor.

Experiment 1: Face-gender discrimination

The experiment consisted of two distinct tasks: an attentionally demanding, central letter discrimination task, and a peripheral, face-gender discrimination task. These tasks were performed in three conditions: blocks of the central or peripheral task alone, or a dual-task condition in which both central and peripheral tasks were performed concurrently. Subjects were instructed to be as accurate as possible, and no constraint was imposed on their reaction times. An auditory tone was provided as feedback on incorrect trials. The experimental timeline for one trial is illustrated in Figure 1. In all three conditions, the trials were arranged as shown in the figure and only the specific instructions to participants differed.

Central letter discrimination task

The attentionally demanding central task consisted of letter discrimination. Each trial started with a fixation cross presented 300 ± 100 ms before the onset of the first stimulus. At 0 ms, five randomly rotated letters (Ts and Ls, either all the same or one different from the other four) were presented at the center of the display at nine possible locations within 1.2° of fixation. Participants were required to report whether the letters were identical or not by pressing one of two keys on the keyboard. The letters were individually masked by an "F," rotated by an angle corresponding to the "T" or "L" it replaced. The stimulus onset asyhchrony (SOA) was determined individually for each participant (see "Training" below).

Peripheral face-gender discrimination task

A face subtending approximately 2.5° of visual angle was presented peripherally 26 ms following the onset of the central stimulus. The face appeared at a random location centered on an edge of an imaginary rectangle subtending 8° x 10°of visual angle. Each face was masked by a pattern mask composed of scrambled faces; the peripheral stimulus was always masked before the central stimulus. The peripheral SOA was determined individually for each participant (see "Training" below). Participants were required to report the gender of the face using two keys on the keyboard.

Dual-task

In the dual-task condition, participants were asked to respond to both the central task (with the left hand) and the peripheral one (with the right hand), and fixate at the center.

Training

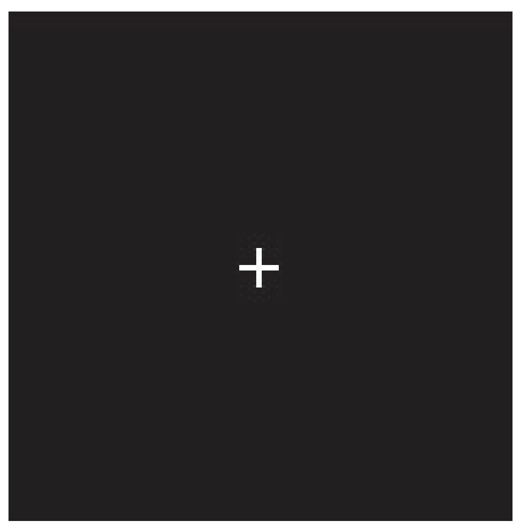
At the beginning of training, the letters were displayed for 500 ms and the faces for 160 ms before the mask appeared (Figure 1; see also Movie 1). Through the course of training, the "letter" and "face" SOAs were decreased (when mean performance in a 48-trial block exceeded 90%). To limit the possibility of eye movements, the letter SOA was decreased to below 250 ms for all subjects. Thus, training was complete when participants' letter SOA had stabilized below 250 ms for a 1-hr session. After training, over the group of participants, the "face" SOA varied between 133-160 ms and the "letter" SOA between 173-240 ms. This procedure, coupled with the high motor demands of the dual-task paradigm, meant that participants required extensive training (between 6 and 12 hr per participant). For three of the six participants, one set of 350 randomly selected faces (7 views of 50 individuals) was used as stimuli, while the other three participants were trained on a different set of 350 faces. Participants received the same amount of training in all tasks.

Data collection

Once training was complete, the letter and face SOAs were fixed for each subject and data were collected over five 1-hr sessions. Each session consisted of four blocks of 48 trials in each single-task condition and six blocks of 48 trials of the dual-task condition. A session was considered valid if dual-task letter performance was not significantly lower (*t* test, $p > .05$) than single-task letter performance. This served to ensure that participants were effectively focusing attention on the central letter task. Over the six participants, only two sessions were rejected as a result of this criterion.

Experiment 2

In a separate dual-task session, all six participants from Experiment 1 were asked to perform gender discrimination on a set of novel stimuli (7 views of the 50 individuals they had not seen in Experiment 1) using the same method as previously, but with no further training. Participants performed only one session of this type.



Movie 1. A graphic demonstration (not to scale) of our basic dual-task experiment (Experiment 1). Note that timing is not accurate but the movie has been slowed down for clarity Demonstration of the stimulus. Click on the movie to view.

Experiment 3

Experiment 3 was performed on the same day as Experiment 2 with participants (except the author LR) from Experiments 1 and 2. In two separate sessions of this experiment, participants were presented with the faces they had viewed during Experiment 1 (the "familiar" images) and Experiment 2 ("control" faces), respectively, along with an equal number of faces they had never seen before. Each face was shown centrally for 1000 ms. Participants reported whether they recognized the face or not using two keys on the keyboard. The first session was run before and the second after Experiment 2.

Experiment 4

In a separate set of experiments, six participants who had been trained on a different dual-task experiment (Li et al., 2002) were tested in our paradigm for 1 hr per day for two consecutive days. These participants had been trained on the same central letter discrimination task, but a different peripheral task (animal vs. non-animal and vehicle vs. non-vehicle discrimination). In this experiment, they viewed a different image set each day. In the paradigm they had been trained on, these participants responded to the peripheral stimulus by releasing the mouse button. Thus, instead of reporting whether the face presented was male or female with different keys on the keyboard, three of these participants were asked to release the mouse button if the face was male, while the other three released the button if the face was female.

Experiment 5

In a final experiment, six new participants were tested. They were trained on three different peripheral tasks: upright face-gender discrimination (i.e., the same task as in Experiments 1 and 2), inverted face-gender discrimination (i.e., where each face was rotated by 180°), and a discrimination between two color patterns (a vertically bisected disk with red and green halves or such a disk rotated by 180°). In individual dual-task blocks, participants performed both the central letter discrimination task and one of the three peripheral tasks. Each session consisted of four blocks of the single central-letter task, two blocks of each single peripheral-task, and three blocks of each dual-task. The faces were masked by a pattern mask composed of scrambled faces (as before), while the disks were masked by a disk divided into four red and green alternating quadrants. The tasks were matched for difficulty such that single-task performance for all three peripheral tasks was on average 75%. Participants received an equal amount of training on the three peripheral tasks. The same face set and training and data collection methods were used as in Experiment 1.

Data analysis

A one-way ANOVA and paired t tests were computed for each experiment to compare single and dual-task performance. An alpha value of .05 was used for all statistical tests. Normalized performances in the dual-task experiment were calculated by a simple linear scaling of the mean value of each participant's performance. The scaling mapped the mean single-task performance to 100%, leaving chance at 50%:

$$\text{Normalized performance} = 1/2 + 1/2[(P_2 - 1/2) / (P_1 - 1/2)] \quad (1)$$

where P_2 and P_1 refer to performance in the dual-task and single-task conditions, respectively.

Results

The effects of attentional manipulation on face-gender discrimination were studied with a dual-task paradigm in which participants performed a central attentionally demanding task as well as a second peripheral face-gender discrimination task either concurrently or separately. The role of attention on gender discrimination was measured by comparing performance on the peripheral task, when this task was performed alone (single-task condition), with performance under dual-task conditions. If gender discrimination requires little or no attentional resources, peripheral performance will suffer minimally in the dual-task condition compared to the single-task condition. If, however, the peripheral task does require attention, performance should be severely impaired under the dual-task condition (Sperling & Melchner, 1978; Braun & Sagi, 1990; Braun & Julesz, 1998).

The attentionally demanding central task consisted of letter discrimination. Participants were presented with five randomly rotated letters (Ts and Ls, either all identical, or one different from the other four) at the center of the display and asked to report whether they were identical or not. This task has been shown to be effective in engaging spatial attention at the center of the display (Braun & Julesz, 1998; Lee et al., 1999). Following the onset of the central stimulus, a masked face was presented peripherally Figure 1a; see also Movie 1), and participants had to report the gender of the face. In the dual-task condition, participants were asked to respond to both the central letter task, and the peripheral face-gender discrimination task, while focusing attention on the letter task.

In Experiment 1, six participants were tested on this paradigm (Figure 2). Their performance on the central letter discrimination task when performed alone was on average 83.1% ± 4.1% ($M \pm SD$). This value can be compared with performance on this task in the dual-task condition (83.4% ± 5.6%): If a participant's attention is engaged by the central letter task, performance in the dual-task condition should be equivalent to performance in the single-task condition; otherwise, there should be a significant decrease in performance levels. For our participants, there was no significant difference in performance on this task between the single and dual-task conditions(t test, $p > .05$). When participants performed the face-gender discrimination task

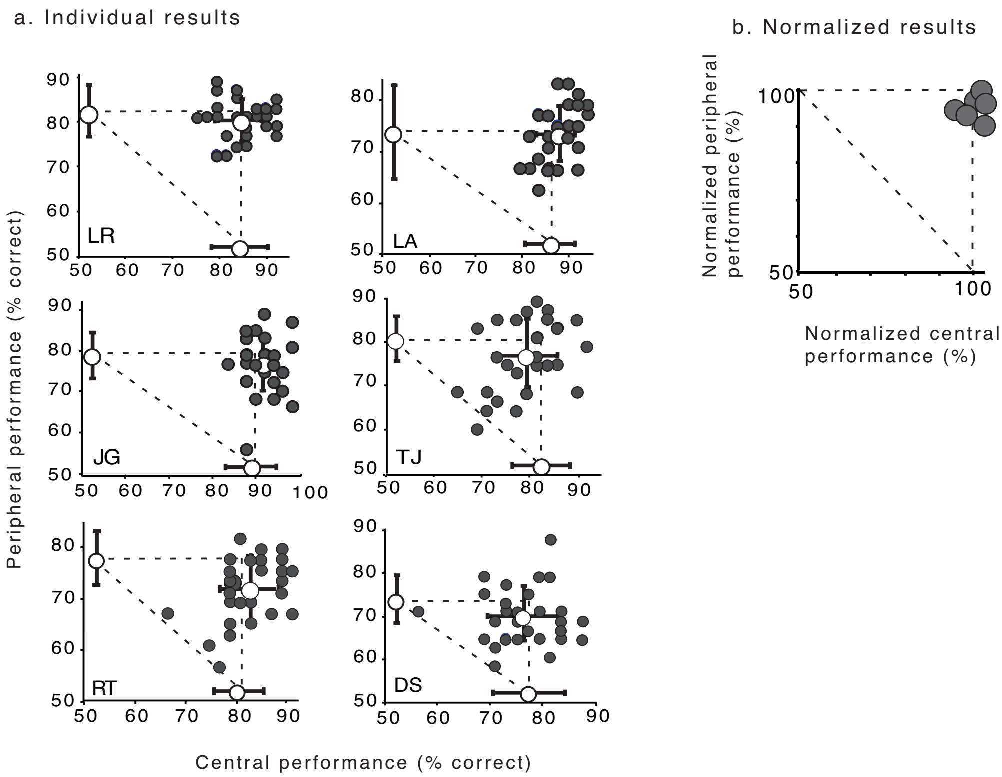


Figure 2. Results from six participants in the dual-task paradigm. a. The horizontal axis represents performance on the attentionally demanding central letter task. The vertical axis represents performance on the peripheral gender discrimination task. Each filled circle is the participant's mean performance in the dual task in one block of 48 trials, whereas an open circle represents mean performance in the three experimental conditions: single central task, single peripheral task, and the dual task. By default, performance of the "to-be-ignored" task is assumed to be at chance level (50%) in the single-task condition. Error bars represent SD. For all participants except one (RT), face-gender discrimination performance in the dual-task condition is not significantly worse (*t* test, p >.05) than performance in the single-task condition, indicating that face-gender discrimination suffers only minimally when performed concurrently with an attentionally demanding task. b. Normalized average performance for each participant in the dual-task paradigm. Each point represents a participant's performance in the dual-task normalized to their single-task performance. Normalized values are obtained by a linear scaling that maps the average single task performance to 100%, leaving chance at 50% (see "Methods"). Normalized gender-discrimination performance values lie above 90% of single-task performance, suggesting that participants can perform face-gender discrimination remarkably well in the near-absence of attention.

alone, performance was on average 77.6% ± 3.8%. This comparatively lower value reflects the short stimulus exposure and the fact that obvious gender cues, such as the presence of facial hair, were removed from the images. Performance on this task in the dual-task condition (74.9% ± 4.0%) was also not significantly different ($F(1, 10) = 1.52$, $p = .2$) from performance in the single-task condition over the group of six participants (Figure 2a). For five of the six participants, individual *t* tests revealed no significant difference in performance (p >.05) between these two conditions. Figure 2b summarizes these results: In the face-gender discrimination task, performance for all six participants in the dual-task condition was above 90% of their performance in the single-task condition (normalized plot; see "Methods"). These results indicate that although there is a decrement in the dual-task condition, face-gender discrimination can still be performed efficiently with little or no attentional resources available, and constitute the main finding of this study.

To limit the possibility of eye movements, the central SOA was maintained below 250 ms for all participants, and the peripheral stimulus could appear anywhere at one of eight peripheral locations. This constraint, together with the high motor demands of the dual-task procedure, meant that participants required extensive training (between 6 and 12 hr per participant) with the same set of male and female images (referenced hereafter as the "familiar" face set). Consequently, it could be argued that instead of performing gender discrimination as required, participants were actually using a strategy akin to face recognition. To control for this potentially confounding effect, the same participants were tested on a set of novel faces ("control" faces) in Experiment 2 (Figure 3a). Despite the novelty of the control face set, over the group of participants, the difference in performance on gender discrimination between single

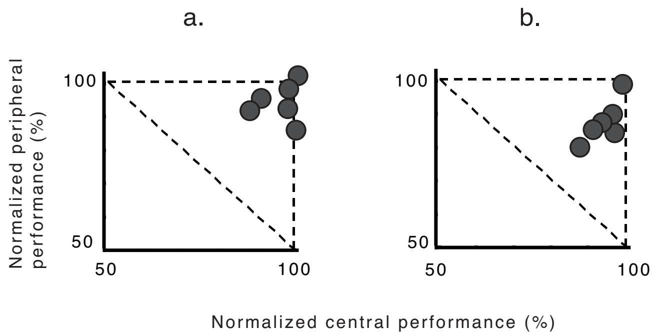


Figure 3. Normalized average performance on the dual-task paradigm with novel images and participants unfamiliar with the face-gender discrimination task. a. Normalized average performance for six participants in the dual-task paradigm using a completely novel set of faces. (Notation as in Figure 2b). Normalized dual-task performance lies above 85% of single-task performance for all participants, indicating that even with a novel set of faces, gender discrimination is performed well under the dual-task condition. b. Normalized average performance for six participants who had been trained on a completely different dual-task paradigm. Normalized dual-task performance lies above 80% for all participants. This suggests that in spite of unfamiliarity with the gender discrimination task, performance was only marginally impaired in the dual-task condition.

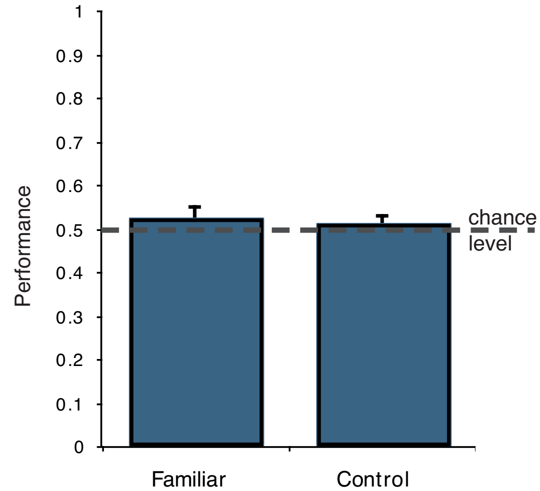


Figure 4. Results from participants (the same as those shown in Figure 2 and 3a) on the face recognition control experiment. Participants were presented with faces they had viewed during the study, and an equal number of novel faces, and asked to report whether they recognized the face or not. The "familiar" image set is the one participants were trained on, whereas the "control" faces had been viewed only twice each. In both cases, participants are at chance level at discriminating previously seen faces from novel faces, indicating that they had formed no explicit representation of the face sets. Error bars represent SD.

and dual-task conditions was not significant ($F(1, 10) = 1.43$, $p = .3$). Individually, for five of the six participants, performance was not significantly different between these two conditions (79.1% ± 4.8% and 75.6% ± 5.1%, respectively; paired t test, $p > .05$). Although there was a modest decrement in the dual-task condition, face-gender discrimination performance for all six participants was above 85% of their original single-task performance (normalized plot, Figure 3a). Note that the central task performance in the dual-task condition was not significantly lower than performance in the single-task condition for each participant (t test, $p >. 05$), indicating again that attention was effectively engaged at the center in the dual-task condition. From this control experiment, it appears that familiarity with the face set is not critical to the observed performance. In fact, results from an additional control experiment (Experiment 3) indicate that participants had not gained any appreciable familiarity with either of the face sets they had viewed during Experiments 1 or 2. In separate sessions, participants were presented with the faces viewed extensively during the training and data collection phases in Experiment 1 ("familiar" faces), or faces viewed in Experiment 2 ("control" faces), as well as an equal number of completely novel faces. (The "familiar" faces had been viewed between 18 and 30 times, while the "control" faces had each been viewed twice during the course of Experiments 1 and 2, respectively.) Each presentation of the face had lasted between 143 ms and 160 ms, depending on the participants' SOA (see "Methods"). Participants were asked to report for each face whether they had seen it at least once during Experiment 1 or 2. Surprisingly, for both the "familiar" and the "control" sets of images, participants' performance on this recognition task (52.1 ± 3.4% for the familiar face set and 51.1 ± 2.2 % for the control face set, Figure 4) was not significantly different from chance levels ($p = .2$, $p = .4$, respectively, paired t test). Thus, it appears that despite having viewed some of the faces repeatedly, participants were unable to differentiate the stimuli in either face set. These results confirm that the pattern of performance observed in Experiments 1 and 2 cannot be accounted for by familiarity with the stimuli used.

Because participants had been extensively trained on the face-gender discrimination task, it could still be argued that they had learned low-level features in the image set, which would contribute significantly to the observed performance. To control for this, six new participants were tested on our gender-discrimination task (Experiment 4). They had been trained on a completely different dual-task experiment (natural scene categorization: animal vs. non-animal or vehicle vs. non-vehicle) (Li et al., 2002). Data were collected over two days with a new set of stimuli on each day. Despite the novelty of the peripheral task, participants performed comparably well in the dual-task and single-task conditions (Figure 3b). While performance on the gender-discrimination task was significantly lower ($F(1, 10) = 5.4$, $p = .04$) in the dual-task (69.7 ± 5.6%) versus single-task (75.91 ± 6.2%) condition over the group of participants, there was, individually, no significant difference in performance for four of the six participants (p >.05, paired t tests). The normalized results shown in Figure 3b indicate that despite the novelty of the task, performance in the dual-task condition was above 80% of performance in the single-task condition for all six participants. We conclude therefore that there was no strong or consistent confounding effect of training in our gender discrimination task.

Thus, whether involving highly familiar or completely novel faces, or even a completely novel discrimination task, there is only a modest decrement in performance on face-gender discrimination in the near-absence of attention.

Finally, to rule out the possibility that low-level cues in the face dataset could account for the observed results, we tested six additional participants in Experiment 5. In this experiment, participants were required to perform face-gender discrimination on both upright and inverted faces, using the same method as Experiment 1. Inverted faces provide a suitable control for basic low-level characteristics (e.g., contrast, luminance, spatial frequency, etc.) that might aid gender discrimination. If the observed results were due to low-level statistical properties of male and female faces, equally high levels of performance would be observed in both the upright and inverted face-gender discrimination tasks.

Participants received the same amount of training in both the upright and inverted face-gender discrimination tasks, and the level of difficulty was matched so that the mean single-task performance was about 75% for both tasks. Consistent with the results of Experiments 1 and 2, participants again achieved a high level of performance on upright face-gender discrimination in the dual-task condition compared to the single-task condition (Figure 5a; 71.3% ± 3.4%, 75.5% ± 4.0%, respectively; see also Figure 6). Over the group of six participants, a one-way ANOVA revealed no significant difference in performance in the dual and single-task conditions ($F(1, 10) = 3.62$, $p = .09$). Individually, there was no significant difference between these two conditions for four of the six participants (t test, $p > .05$), and all six participants performed above 85% of their original single-task performance. In contrast, based on a one-way ANOVA, the six participants showed a significant decrease in performance ($F(1, 10) = 25.7$, $p < .001$) in the inverted face-gender discrimination task when attention was unavailable compared to the single-task condition (59.7% ± 4.7%, 71.7% ± 3.3%, respectively), and individual tests for each participant revealed a significant decrease in performance in this dual-task condition for all six participants (t test, $p < .05$; Figure 5b). Further, for each of the six participants, performance in the inverted dual-task condition was significantly lower than performance in the upright dual-task condition ($p < .05$, t test). We conclude that the observed performance in upright face-gender discrimination cannot be accounted for by the low-level statistical properties of the stimulus set.

The interpretation of the results reported here relies on the assumption that the central letter task efficiently engages attention in the dual-task condition and that performance on attentionally demanding tasks should suffer dramatically in the dual-task condition. As a further control, we verified that performance on a known attentionally demanding task would indeed be severely impaired in the dual-task condition (Braun & Julesz, 1998; Li et al., 2002). We had the same six participants discriminate between a

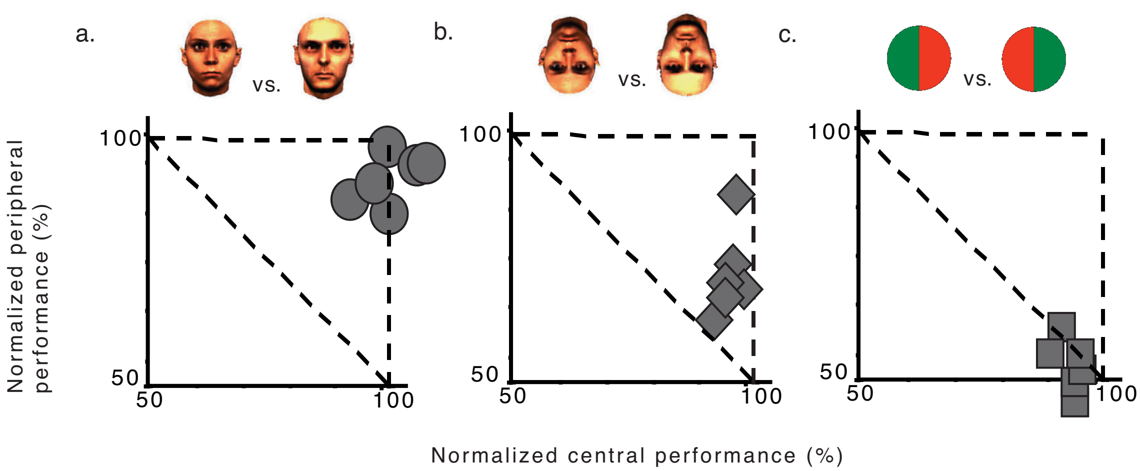


Figure 5. Normalized dual-task results of six participants in three tasks. a. Upright face-gender discrimination task. Normalized dual-task performance values are on average 92% of single-task performance levels for upright face-gender discrimination, as expected from results shown in Figure 2b. b. On the other hand, in the inverted face-gender discrimination task, normalized dual-task performance values are on average 72% of single-task performance levels, demonstrating that in the near-absence of attention, performance is impaired. In addition, for each participant, there is a significant decrease in performance when the task involves inverted faces compared to upright faces. Thus low-level visual cues cannot account for the pattern of results obtained in the upright face-gender discrimination task. c. Color pattern discrimination task. Normalized dual-task values are on average 53%, demonstrating that attention is effectively withdrawn by the central letter task in dual-task conditions.

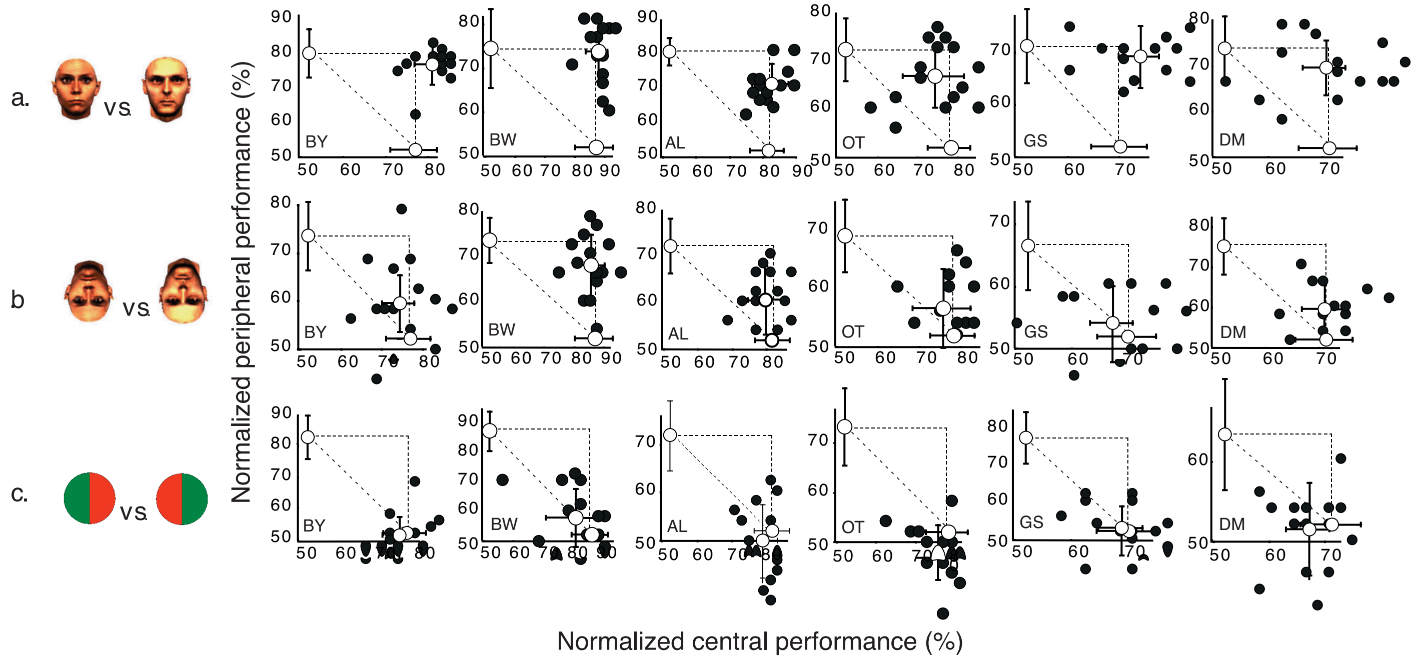


Figure 6. Raw data for Experiment 5. Dual-task results of six participants in three tasks. The horizontal axis represents performance on the attentionally demanding central letter task. The vertical axis represents performance on the peripheral gender discrimination task. Each filled circle is the participant's mean performance in the dual task in one block of 48 trials, while an open circle represents mean performance in the three experimental conditions: single central task, single peripheral task and the dual task. By default, performance of the "to-be-ignored" task is assumed to be at chance level (50%) in the single-task condition. Error bars represent standard deviation. *(a)* Upright face-gender discrimination task. *(b)* Inverted face-gender discrimination. *(c)* Color pattern discrimination task.

masked color disk and its mirror image in the dual-task condition. In our experiment, participants received the same amount of training in all three discrimination tasks (upright face-gender, inverted face-gender, and colored-disk discrimination), and task difficulty was matched so that single-task performance was about 75% for all three tasks. In contrast to the results observed for upright face-gender discrimination, and consistent with previous studies (Braun & Julesz, 1998; Lee et al., 1999; Li et al., 2002), we observed (Figure 5c) a dramatic decrease in performance over the group of six participants when the colored-disk discrimination task was performed in the dual-task versus single-task condition (51.8% ± 3.4%, 76.1% ± 8.5%, respectively, $F(1, 10) = 42.0$, $p < 10^{-4}$). As shown in Figure 5c, normalized performance values were between 45% and 60% of single-task levels, and for five of the six participants these values were not significantly different from chance levels of performance (paired t test, $p > 0.1$). These results confirm that under our experimental conditions, the attentional requirements of the central task result in a clear decrease in dual-task performance.

Discussion

Our findings demonstrate that telling male from female faces, a fine discrimination task, can be performed remarkably well when spatial attention is engaged elsewhere. We have shown that participants can achieve a high level of performance in the presence of little or no focal attention when they are tested on a set of completely unfamiliar faces, even when they are unfamiliar with the task itself. Further, when participants perform the same face-gender discrimination task in the near-absence of attention on a set of inverted faces, performance is significantly impaired compared to performance on this task with upright faces. These results demonstrate that the observed findings cannot be attributed to low-level characteristics of the image set. Previous psychophysical studies have shown that face recognition is impaired when the faces are inverted rather than upright (Yin, 1969; Valentine, 1988; Valentine & Bruce, 1988; Brown et al., 1997). Additionally, while functional imaging studies have suggested that inverted face processing recruits additional brain areas compared to upright face processing (Haxby, Ungerleider, Clark, Schouten, Hoffman, & Martin, 1999), electrophysiology in monkeys has revealed that although face-specific cells respond to inverted faces, the responses are weaker and longer in latency compared to those evoked by upright faces (Perrett et al., 1988). Our results suggest a differential requirement of spatial attention by these two tasks: The absence of attention has a pronounced effect on the processing of inverted faces, but not upright faces.

It should be noted that while 19 of the 24 datasets we obtained overall did not demonstrate any significant decrease in performance in the dual-task conditions, the remaining five did show some decrement. However, some decrement in performance is expected to occur when participants perform two demanding tasks concurrently, compared to when the tasks are performed alone. These performance decrements do not necessarily imply competition for an attentional resource, but could be attributed to other factors, such as having to maintain two sets of task goals or having to encode and produce two sets of responses (Allport, 1980; Duncan, 1980; Pashler, 1984, 1994). In addition to comparing single and dual-task performance, it is revealing to compare the dual-task performance of our participants in the face-gender discrimination task with dual-task performance on tasks that are known to require attention(Braun & Julesz, 1998; Li et al., 2002). As we have shown, performance on a known attentionally demanding task (discriminating a red-green from a green-red disk) drops to chance levels when the available spatial attention is severely reduced. In contrast, performance on our face-gender discrimination task remains consistently above 80% of single-task performance when attention is engaged elsewhere. Indeed, a statistical comparison of all 24 datasets we collected indicates that all our participants perform face-gender discrimination in the dual-task condition significantly above chance (t test, $p < 10^{-16}$).

From a computational perspective, we designed our peripheral task to be challenging: This task did not merely involve the discrimination of targets and distracters at a basic level of categorization, but required a fine discrimination within a category level, between male and female faces that share the same overall structure and lack hair and other obvious gender cues. In essence, this meant a fine discrimination of the spatial arrangement of highly similar features present in both targets and distracters. Our results indicate that such discrimination can be carried out in the presence of a primary task highly effective in requiring attentional resources (Braun & Julesz, 1998; Lee et al., 1999; Li et al., 2002). This supports the notion that the "complexity" of a task as measured by its computational demands does not necessarily determine its attentional requirements. Classical views of selective, visual attention have suggested that while simple salient stimuli can be detected outside the focus of attention, attention plays a key role in the recognition of more complex stimuli. In other words, it has been proposed that attention is necessary to combine the different low-level features of a stimulus into a coherent representation of the object (Treisman & Gelade, 1980). Access to this representation is supposed to be necessary for object recognition and behavior. Our findings argue that face-gender discrimination is possible in the near-absence of attention. Although this conclusion cannot be generally extended to other sub-ordinate level categorization tasks involving natural stimuli, our approach shows that attention is not always necessary for such tasks. The possibility that faces hold a special status for the visual system is still under debate (Farah, 1995; Gauthier & Tarr, 1997; Kanwisher et al., 1997; Farah et al., 1998; Tovee, 1998; Gauthier, Skudlarski, Gore, & Anderson, 2000; Ro et al., 2001; Bogen & Berker, 2002). It would thus be interesting to test the role of attention in other "complex" discrimination tasks, and determine whether expertise in other areas yields similar results.

If a failure to pop-out during a search task is taken to indicate the necessity of focal attention for recognition, then our results appear to contradict a number of studies that have shown that facial information does not "pop-out" in a visual search situation (Nothdurft, 1993; Kuehn & Jolicoeur, 1994; Purcell et al., 1996; Brown et al., 1997). However, it is worth noting that earlier studies had suggested that faces can be processed in parallel (Hansen & Hansen, 1988), and this issue is still controversial and open to debate (Hochstein & Ahissar, 2002). Furthermore, the correspondence between dual-task and visual search results has recently been called into question (VanRullen, Reddy, & Koch, 2003). More supportive evidence for the preattentive processing of faces comes from clinical reports of patients with visual neglect (Vuilleumier, 2000; Vuilleumier et al., 2001). For these patients, extinction was less likely to occur for faces presented in the neglected hemifield than other objects (e.g., meaningless shapes). In other words, faces could attract attention more efficiently, and thus probably had a competitive advantage at the preattentive level. Such observations are compatible with ERP and magneto-encephalography (MEG) investigations of the latency of face or face-gender selective responses, which was found to be on the order of 100-150 ms (Schendan, Ganis, & Kutas, 1998; Yamamoto & Kashikura, 1999; Mouchetant-Rostaing, Giard, Bentin, Aguera, & Pernier, 2000; Liu et al., 2002). Given this remarkable speed, one wonders whether such processing can depend critically on visual attention.

In neural terms, several electrophysiological investigations have found single neurons responsive to faces in the infero-temporal cortex of monkeys, the "end-point" of the ventral visual hierarchy (Gross, Rocha-Miranda, & Bender, 1972; Bruce, 1982; Perrett, Rolls, & Caan, 1982; Desimone, Albright, Gross, & Bruce, 1984; Perrett et al., 1984; Rolls, 1984). Similar observations have been made in humans in medial temporal lobe structures (Kreiman, Koch, & Fried, 2000). Several neuro-imaging studies have shown the existence of higher-level brain regions (such as the fusiform face area [FFA]) that selectively process facial information (Sergent, Ohta, & MacDonald, 1992; Haxby, Horwitz, Ungerleider, Maisog, Pietrini, & Grady, 1994; Kanwisher et al., 1997; Kanwisher, McDermott, & Chun, 1999), although some models of face recognition have conjectured that gender discrimination could occur in more posterior temporal areas (Bruce & Young, 1986). Consequently, it is not unreasonable to suppose that our stimuli differentially activate neurons in such high-level areas, and that gender discrimination can rely on the selectivity of these neurons. Some evidence shows that these areas can be modulated by attention (Wojciulik, Kanwisher, & Driver, 1998; O'Craven, Downing, & Kanwisher, 1999; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002), but the present results indicate that the residual activity in the near absence of attention is sufficient for the efficient processing of faces. Our findings, together with those of Li et al. (2002) and Rousselet et al. (2002), suggest that the activation of such high-level neuronal populations can take place in the near-absence of attention.

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